No farmer's wife who had to get her supply of water from a pump way across the back yard had anything on us. We had to pump our water from the creeks in barrels when the greens needed watering, as water pipes were noticeable by their absence. In 1904 or 1905 I used the first corrosive sublimate for worms, and tried out sulphate of ammonia as a fertilizer. In 1904 the club acquired some property on which I built another nine holes, and they are still playing on some of them.

In 1917 I was given a position as greenkeeper at the Pittsburgh Field Club where I have since remained.

My twenty-five years of experience have taught me that the golf courses of this country must be kept by men who have through study, observation and practical experience, learned that keeping good greens is widely different from farming or gardening. Golf turf is worn by countless feet, and much of its area is grown under unnatural conditions.

Although good greens are the mark of the good greenkeeper, I feel that a few words in defense of patchy fairways are in order.

Fairways Need Fertilization

On many courses throughout the country fairways are allowed to go year after year with a little re-seeding here and there, but with no application of fertilizer to speak of. Turf is a greedy crop, and unless the elements upon which it feeds are replaced in the soil as fast as they are used by the grass plants, no amount of re-seeding will produce an even healthy growth of fairway turf. After a time, the club members wonder why the fairways have so many weeds and so little grass. Fairways must be fertilized every two or three years, if the grass is to maintain a thick stand and keep the weeds out.

Another direct cause of prevalence of weeds on some fairways is rolling while the ground is too wet. I have always preached this to the chairmen of the Green, but many still have in their heads that fairways must be rolled before they get too dry. There are many times spots on fairways which should be on the dry side before rolling. Thereby the grass on these spots is saved, instead of pinched out and leaving a space for weeds to take possession of as soon as rapid growth starts.

There is good equipment now on the market for golf courses, but manufacturers should devote some time to designing a good fairway top-dresser. Spreading top dressing by hand is an expensive process, but fertilizer must be applied if we are to maintain good fairways.

The A B C of Turf Culture

Physical Properties of the Soil and Their Effect on Turf Production

By O. J. NOER
Fellow, Department of Soils, University of Wisconsin

Author's Note: It has been my privilege to learn the theoretical side of turf culture, and after that to test that knowledge in practical field work on the farms and golf courses of the Middle West. The publishers of THE NATIONAL GREENKEEPER tell me that I can help the greenkeepers to a better understanding of their problems. I am willing to try, and if my readers are interested and want to ask questions about turf culture I shall be glad to answer them through the columns of the GREENKEEPER.

The soil as indicated in a previous article consists of mineral particles derived from the waste of rocks, humus resulting from the decay of plant and animal residues, and spaces between the individual soil particles which contain air and water. The size of the individual soil particles, and the way in which they are arranged greatly affect the producing power of the soil.

Size of Soil Particles Determines Texture

The texture of the soil depends upon the size of the individual soil grains.

O. J. Noer

Many soil properties, such as water holding capacity, workability, and power to supply the plant with essential mineral food elements depend upon texture. For practical purposes the individual soil particles are arbitrarily grouped into classes based on size. The limits of the different groups are determined by the relative value of the various sized particles in affecting the physical properties and crop producing power of the soil. Seven groups are recognized, namely—fine gravel; coarse, medium, fine and very fine sand; silt and clay. The relative size of the particles of these seven different groups is illustrated below. Actually the various particles are 1/800 the size represented. The number of fine particles in a

given volume is very great. In one gram (453.69 grams equal 1 pound) there are the following number of individual particles for the classes indicated.

Clay	45,000,000,000
Silt	65,000,000
Very fine sand	2,000,000
Coarse sand	2,000

With these enormous differences is there any wonder that differences of texture exert such an enormous effect upon the properties of the soil. Sand and clay are most important, so some of their distinctive properties deserve special attention. Humus exerts a marked effect on soil structure but will be dealt with in a future article.

Sand

Sand consists mainly of grains of quartz, although other minerals are also present, especially in the fine grained sands. Due to the abundance of quartz, sands are generally low in plant food constituents. Considered in the mass the chief characteristic of sand is its lack of coherence, or ability to retain its form especially when dry. Soils containing large amounts of sand have a low water holding capacity, and are not well adapted to turf for reasons which will be considered under soil moisture.

Clay

The finest soil particles constitute the group clay, a material possessing unusual properties, which are most apparent when clay is puddled, or worked when wet. In puddled clay the individual particles are so closely packed that even thin layers prevent the passage of water. Moist clay is plastic and can be worked into shapes which it still retains upon drying, and the mass becomes very hard and tenacious.

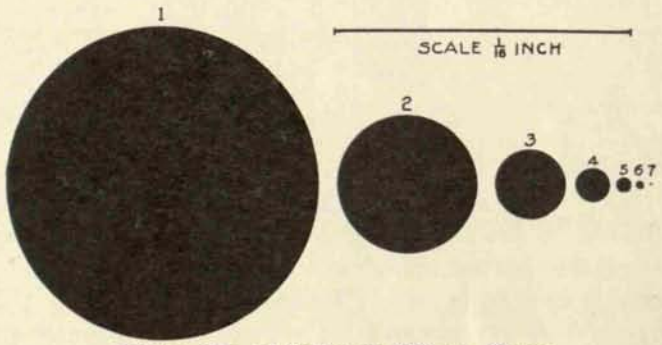
If a small amount of clay is rubbed up into water, the water becames clouded and even after long standing the minute clay particles still remain in suspension. The addition of small amounts of certain substances cause the fine suspended particles to clot or form larger aggregates which rapidly settle to the bottom of the container. This power of clay to clot or form larger aggregates occurs in the soil mass and plays a very important part in the management of soils high in clay. When the clay is in the state of aggregation the soil behaves as though it were composed of coarser particles. Just as the potter works clay to break the aggregates into the ultimate particles to make the clay more plastic, so working clay soils when too wet destroys the aggregates and makes the soil more clayey than before. The soil then becomes more impervious to the passage of water and air, and dries into hard, tenacious lumps. To make it more tractable is difficult and requires time. It is accomplished by the action of weather, such as freezing and thawing, alternate wetting and drying, the incorporation of organic matter, and the action of lime is particularly effective.

Soils Grouped Into Classes Based on Texture

The fact that soils consist of a mixture of different sized particles is generally recognized. Yet a soil may contain a large proportion of particles of uniform size. Thus a sandy soil contains a large proportion of sand, and the larger the proportion the coarser the sand. A clay soil contains a large proportion, but not necessarily a larger proportion of clay than material of any other size, because a given amount of clay has a larger effect upon the properties of the soil than the same amount of coarser sand particles. For practical purposes, soils are grouped into the following classes based on texture.

Sands (Usually Poor Turf Soils)

Contain 80% or more of sand; 20% or less of silt and clay. A sand may be coarse, medium, fine, or very fine depending upon the predominance of the different groups of sand particles.



Relative Size of Grains of Different Classes

1. Fine Gravel	.039 -.078 inches
2. Coarse Sand	.019 -.039 inches
3. Medium Sand	.01 -.019 inches
4. Fine Sand	.004 -.01 inches
5. Very Fine Sand	.002 -.004 inches
6. Silt	.0002-.002 inches
7. Clay	less than .0002 inches

Loams (Generally Good Turf Soils)

Sandy loam contains 20 to 50% clay and silt; 50 to 80% sand. Loam contains 20% or less of clay; 50% or less of silt; balance sand.

Silt loam contains 20% or less of clay; 50% or more of silt; balance sand.

Clay contains 20 to 30% clay; 50% or less of silt; balance sand.

Clay, over 30% clay; balance silt and sand.

With a little experience it is easy to place a soil in its proper class right in the field. Texture is judged by rubbing the soil between the thumb and finger and with experience one soon becomes expert in judging the size of the soil grains.

The best soils for golf courses are undoubtedly the sandy loam, loam and silt loams. Sands are not well suited to turf, and although good turf can be obtained on the clay loam and clay soils, these soils require very careful management.

How Soil Texture Can Be Modified

The only feasible method of modifying soil texture

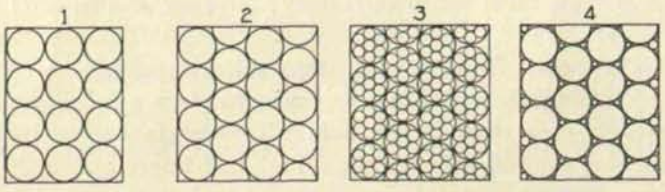
is by adding to it material of different texture. Obviously the huge expense generally prohibits such practice on fairways, but it is entirely practical in the preparation of soils for greens. It is necessary to add more sand to a fine textured soil, than clay to a sandy soil, because clay exerts a greater effect than the same amount of sand. The importance of modifying soil texture before planting greens is especially important, because texture is not easily modified after turf is once established. I have been asked to make fertilizer recommendations for greens, when the poor stand of turf was actually due to the unfavorable soil texture. Fertilizers do not materially improve turf on such greens.

Soil Structure Depends Upon Arrangement of Soil Particles

While texture is of great importance, the arrangement of the individual soil grains is also important. Texture refers to the size of the particles, but the arrangement of the grains determines soil structure. The structural condition influences the circulation of air and water in the soil both of which are necessary to the normal development of turf. In clean sand each individual particle is a unit by itself and has but a chance arrangement in relation to the surrounding grains. Highly fertile soils have a marked structure. The individual grains are bunched, and more or less rigidly bound into groups, granules or crumbs. This arrangement is essential in soils of fine texture (clay loam etc.). Granulation or formation of crumb structure enables these soils to function as though they are more or less coarse grained.

Spaces Between Soil Particles

Collectively the spaces existing between soil particles is known as the pore space. Theoretically, in a soil made up of equal sized spheres in contact with one another, the amount of pore space depends solely on the arrangement of the spheres. Thus a cubic foot of marbles contains as much pore space as one of small shot with the same arrangement of spheres.



Ideal Arrangement of Spherical Soil Particles
1. Columnar order, 47.64% pore space
2. Oblique order, 25.95% pore space
3. Compound spheres in Oblique order, 74.05% pore space
4. Three sizes of spheres with closest packing, about 5% pore space

If small spheres exist within larger ones, the pore space is materially increased. This is the condition in granulated soils. Where there are spheres of several sizes, and the smaller ones occupy spaces between the larger ones the pore space is materially reduced. This is the condition in puddled soils. By working clay soils when too wet the small particles are forced into the spaces between the larger grains. Some ideal arrangements are illustrated in the accompanying cut.

These ideal arrangements do not exist in the soil. The soil grains are irregular in shape and uneven in size. In fine textured soils the smaller particles are so light that they do not settle so closely together in proportion to their size as do the sands. The relation between texture and total amount of pore space for some soils under field conditions is as follows:

	Percent of Pore Space
Clean Sand	33.50
Fine Sand	44.00
Sandy Loam	50.00
Silt Loam	53.00
Clay	56.00

Not only the total amount of pore space but the diameter of the individual pores are of importance. Together they determine the capacity of soil to retain and move water and air, as well as facilitate the extention of plant roots.

Soils Contain Enormous Amount of Internal Surfaces

The amount of surface exposed by the soil particles is of great importance, because it is from these surfaces that the plant roots obtain water and mineral food elements. The water held by a well drained soil exists as a film covering the surface of the particles, and the amount held is dependent upon the surface exposed. The mineral plant food elements are dissolved at the soil surfaces by the soil water, and other things being equal the amount of substance dissolved from a solid body is proportional to the surface exposed. The enormous extent of internal soil surface is not often appreciated. There are more than 10 square miles of surface exposed in the surface foot of an acre of coarse sandy soil, while in a loam more than 60, and in the finest clay more than 300 square miles of surface are exposed. These differences are enormous, and partly account for the greater productive power of the loam and clay soils.

Best Soils Have Granular Structure

The development of crumb structure is necessary in all soils except some of the sands. Water and air pass more freely, and it also permits of more ready penetration of the roots and root hairs. Without granulation the spaces between the particles are so small that the soil is almost impervious to both water and air. Thus if a coarse sandy soil disposes of its excess of water after a heavy rain in 2½ hours, by under drainage, the finest clay without granular structure requires about 3 months to free itself of the same amount of water in a like manner. When the fine soil particles are collected into larger aggregate grains, excess water is quickly

disposed of by under drainage, and there is an opportunity for the roots to advance between the grains, and absorb the plant food and moisture contained in them. Each aggregate acts like a tiny sponge which maintains itself full of water highly charged with plant food materials to be sucked out by the root hairs as they advance alongside them.

When new fairways are to be established on fine textured soils extreme care should be used in the preparation of the seed bed.

Plowing should be done when the moisture condition is such as to prevent the formation of clods. If plowed a season in advance of seeding the alternate freezing and thawing, during the winter improves granulation. If it is possible to grow a green manure crop and plow it under, the resulting humus will materially improve the soil structure.

Ideal soil conditions are most likely to occur in loam soils. These soils have some particles large enough to function separately, and others of medium size to form centers around which the smaller particles may cluster to form granules or crumbs. Thus there are a few large pore spaces which facilitate drainage, and numberless small openings in which water is retained.

Turf Improves Soil Structure

Practical men appreciate the importance of maintaining soils in good physical condition. When seeds begin to grow there is no direct connection between the seed and soil. The small amount of plant food contained in the seed is soon expended in the development of a root system. If the seed is placed in conditions unfavorable for free development of the first roots it may succumb. A mellow seed bed, with many pores allows the roots to grow unhindered and tends to place absorbing surfaces in direct contact with the soil grains. It is particularly important to have a mellow seed bed for turf seedings. The young grass seedling must forage for itself as soon as growth begins because of the exceedingly small amount of food contained in the very small grass seed. After the soil is once covered with grass, the turf aids in improving soil structure. As the roots grow and decay, the soil particles are wedged apart in some places and crowded together in others. The grains are finally cemented together into larger aggregates and the open mellow structure characteristic of virgin soils results.

"Getting Set for the Future"

By FRANK OGG
Greenkeeper, Hillcrest Country Club, Kansas City, Missouri

I WAS born in Carnoustie, Scotland, and like most of the sons of Scotia I cut my milk teeth on a niblick. Therefore being brought up in an atmosphere of golf, I either played golf, talked golf or thought golf all my waking hours.

In 1911 hearing about the wonderful spread of golf in the United States I decided to leave the old country and come where golf has its greatest development.

My first position was with a large seed house in New York with which I was connected for some eighteen months giving me an opportunity to see all of the well known courses in the Metropolitan section. I found things considerably different than they were in Scotland. I found the courses more elaborate and I found a tendency not to rely as much on nature as is the case across the water, but rather to use man's artistry in enhancing natural effect wherever possible.

While I was with the seed company my brother, Willie, who is now at Worcester, Massachusetts came to the Dedham Country and Polo Club as Pro, requesting me to join him as assistant Pro, which I did.

First Experience with Bermuda Grass

After being located there for several years an opportunity came to me to become Pro and Greenkeeper in charge of the course at the Ingleside Club at Atlanta. I had always taken a great deal of interest in greenkeeping although I had no occasion to do anything of this kind at Dedham, the course having been established a long time and under the care of a competent man. I therefore welcomed this opportunity at Ingleside because I had ideas on the subject and I wanted a chance to put them into effect.

At Ingleside I found the grass thin due to lack of sufficient top dressing and found it very coarse which in that particular case was caused by an excess of moisture. This condition I began to correct showing a material improvement within sixty days and I believe the secret of good Bermuda greens lies in first finding if the proper variety of Bermuda has been planted, analyzing the soil conditions, and if the soil is such that it actually will grow good Bermuda and the Bermuda is the right variety it is only a question of care and time until the greens can be brought to the finest possible texture. In this particular case I ceased the use of artificial irrigation almost entirely, generally finding the rainfall sufficient. By carefully following this course of procedure in time I brought all of the greens to a condition of maximum effectiveness.

Ambition Aroused

About this time Dr. E. P. Hinman of Druid Hills, who had been carefully watching my work at Ingleside, sold me on the idea that there was a big field for a man